Photodetector discussion

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- We are pleased that representatives from both Hamamatsu and ADIT/ETL were able to participate in the workshop.
- Both vendors are working hard to meet LBNE needs and at the same time have advanced PMT technology for high energy physics generally. Particularly gratifying is the effort to develop a bulb to withstand the pressures in deep water detectors.
- LBNE has received mechanical samples from both vendors and working tubes from Hamamatsu. The performance of the R11780 - 12" tubes were shown to perform very well in tests at Penn.

- One of the biggest concerns for PMTs in the large water Cerenkov detectors is the resistance to the pressures. An extensive program is underway at BNL to tests the mechanical integrity of the LBNE candidate PMTS.
- Efforts are underway at Drexel and CSU to develop light concentrators that will reduce the requirement for PMTs.
- We heard about the PMTs for the ambitious neutrino detectors being planned for Europe.
- We heard about new types of photodetectors such as the LAPPDs being developed at ANL. The effort includes important photodetectors and readout R&D.
- Other efforts such as HAPDs are being developed/considered in Japan.

Availability

- 3 experiments in 2020+ timescale:
  - LBNE 29K 12” PMT
  - HyperK 99K 20” PMT (12”?)
  - LENA 63K 8” PMT or 12K 12” PMT
- Does the production capability exist for the best case scenario (all 3 experiments go forward)?
- What is the threshold for mass production of phototubes? 100, 1000, 10K, 50K, 100K?
- Standard PMTs vs alternatives such as HAPDs, LAPPDs, etc

Light Collection

- High QE photocathodes composition and thickness (>30%)
  - Stability and uniformity, in large quantities?
  - Characterization by vendors/experiments (stat vs per tube)
- Even higher QE photocathodes
  - Need larger R&D effort? vendors + academic
  - Availability?
- Winston Cones vs WLS plates or both?
  - Replace significant fractions of PMTs, loss of granularity?
  - Loss of angular acceptance vs timing capabilities?
- Higher QE vs Light Collection add-ons
  - Is this 10-20% increases (QE) vs 50-75% (add-ons)?
  - Is 50% QE possible?

Photodetection Properties

- Optical vs equivalent photodetector coverage:
  - LBNE 12% optical, ~20% equivalent
  - HyperK 20% optical?
  - LENA 30% optical
- Impact on detector design/geometry
  - Improvements could lead to different design
  - Granularity and timing for better spatial resolution and PID
  - Small vs large detectors, innovation vs. known unknowns

Durability

- Pressure resistance (10-13 bar)
  - shape, capsule, thickness of glass, other options?
  - mechanical protection against implosion at 80-100m
- Aging issues (20-30 years)
  - Degradation by Exposure to ultrapure water/scintillator
- Options: bare, **partially encapsulated** or **completely encapsulated**.
- Proof testing vs statistical tests
  - Insuring against cascade implosions
- Durability vs environmental properties?
  - E.g. Add potassium nitrate? other additives
- Physics impact of environmental properties
  - Practical limits in lowering concentrations of isotopes?

PMT alternatives

- Quasar (Baikal): solid scintillator block + PMT
  + small jitter even for large photocathodes, excellent energy resolution
  - price
- Hybrid-Gas Photomultiplier: photocathode in vacuum + THGEM
- SiPM: array of small APDs
  + excellent TTS (FWHM< 0.5ns), excellent energy resolution
  - immense cost/area; huge dark count (100kHz- Mhz), cooling needed
- Qupid/HybridPhoto-Detector: Photocathode+APD
- ❖ HAPD: Hybrid Avalanche Photodetector (Toshinori Abe)
  + excellent timing resolution ~200ps; less parts; higher collection
  - unknown availability?; standard QE 20%, smaller gain (10^5)
- Microchannel Plate (MCP): Photocathode + thin etched channels
  + excellent timing resolution
  - small-area, expensive
- ❖ LAPPDs: Large-Area Picosecond Photodetectors (MCP based)
  + large-area 8"+, excellent timing resolution 100 psec, integrated readout
  - unknown cost/area, availability

Most alternatives from Jurgen Winter's talk